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Improving the Quality of Functional Food Crops and Land Efficiency by Intercropping System on Application of Integrated Fertilizer

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ABSTRACT: The intercropping system and integrated fertilizers were applied in the research to improve land efficiency and the quality of sweet corn and vegetable soybean crops. The study was conducted in the Giwangan Village of Umbulharjo Yogyakarta, Indonesia, and was set up using a three-replication factorial Randomized Complete Block Design. Three organic fertilizer sources (cow manure, chicken manure, and composted waste) made up the first factor, and the second factor was NPK fertilizer doses (200, 300, and 400 kg ha^{-1}). Two control treatments were also made, which resulted in 33 experimental plots. The observed data were subjected to analysis of variance and Duncan's Multiple Range Test at a significance of 5%. The study's findings demonstrated that the combination of 300–400 kg ha^{-1} NPK fertilizer and chicken manure increased variables such as the content of vitamin C and pro-vitamin A, number of seed rows, number of 2-3 seed pods, and sweetness level of soybean and sweet corn, as well as the land equivalent ratio, land equivalent coefficient, competition index, system productivity index, and relative yield mixture.

KEYWORDS: Land Equivalent Coefficient, vitamin C, sweet corn, sweetness level, vegetable soybean

INTRODUCTION

The population of Indonesia has increased since 2017 from 263.99 to at 273.51 million people, making it the fourth most populous country in the world [1]. Other than food, clothing, and housing, the population has several needs to maintain a healthy lifestyle. Demand for knowledge, welfare, and health increase in response to population growth. Food must be both sufficient and of high quality in order to meet the demands. Functional food is required to support life quality since it contains the building blocks of health and energy in the form of phytochemicals, vitamins, and mineral [2]. According to Tapolska et al. [3], functional food (FF) influences certain bodily functions, may offer additional health benefits or a cure for certain diseases after the addition/concentration of a beneficial ingredient or removal/substitution of an ineffective or harmful ingredient, and according to Temple [4], contains additional components that are beneficial to health in addition to nutrients. Sweet corn and vegetable soybeans are two examples of functional food crops with great economic value that have recently seen an upsurge in demand.

Through the use of chemical fertilizer, maximum corn productivity can be achieved. However, it's important to keep in mind that human health and the sustainability of agricultural land for future generations are equally important, especially given the country and the world's continued population growth. However, a partial switch from chemical fertilizers to organic and biological fertilizers will preserve soil health and increase the economic stability of farmers [5].

One of the corn varieties with a high sugar content is sweet corn, which also has a high economic value due to its widespread popularity in the community [6]. According to Szymanek et al. (2015)[7], the local variety of corn has a sugar level of 16–18%. As a result, sweet corn is valued as a high-quality food that also tastes great. In addition, corn kernels have a balanced ratio of sugar to mineral, amino acids, and B vitamins, as well as a high content of fiber. According to Das and Singh [8] and Srdic et al. [9], sweet corn also contains phytochemicals that are good for your health, like carotenes, tocopherols, and phenolic acids. In the 1980s, small-scale commercial cultivation of sweet corn cultivars began in Indonesia. The demand for sweet corn is rising as public awareness of the importance of healthy diet rises. With an average productivity of less than 10 tons per hectare, sweet corn productivity in Indonesia is quite poor. Similarly, Srdic et al. [9] stated that the yield potential of sweet corn was 13.33 tons ha^{-1}, however Subaedah et al.[10] revealed that the productivity of sweet corn only reached only a third of yield potential (8.32 tons ha^{-1}). In contrast, the most recent study by Subaedah et al. [11] found that sweet corn grown in twin rows can generate cobs weighing as much as 22.33 tons per hectare.

In addition to being a useful food, soybeans also contain 10–14% protein, vitamins, minerals, high dietary fiber, and vital amino acids. This Japanese variety of legume also contains compounds called isoflavones, which have been shown to have many potential health benefits in humans, including increased antioxidant activity, cancer prevention, and a decrease in the bad LDL cholesterol, which is a major cause of cardiovascular disease. In order to ensure that there are sufficient volumes produced to entice private enterprises to participate in the vegetable soybean value chain, continued efforts to expand the crop, particularly in the key green soybean growing areas, are needed [12]. Besides being a staple source of high-quality food and feed on a global scale, legumes also help to lower greenhouse gas (GHG) emissions because they produce 5–7 times more GHG per unit area than other crops. In addition to helping plants grow and promoting soil nutrient circulation and water storage, this vegetable soybean plant can fix atmospheric nitrogen developed for agricultural soil protection [13]. This is what separates a certain kind of legume from Japanese legumes as a functional food source that can offer customers numerous additional benefits in addition to meeting their basic nutritional demands [14].

Since fertile soil is necessary for the growth of these two functional food crops yet is not available, intercropping system agriculture becomes an option. However, it is unknown if intercropping (IC) inevitably increases soil health status and biomass productivity of all crops. Intercropping is a promising farming strategy used to improve soil health and sustainable crop output. According to Zaeem et al. [15], IC led to a 28% increase in overall forage production. Long beans are one of the many ancient crops that have been cultivated by people in a variety of ancient agricultural systems that have been documented and developed. Possible intercropping was used in many ways by early civilizations, according to historical evidence. The continent of South Asia experiences a variety of plant development due to its varied environment. Furthermore, the IC method, which displays the development of grains with legumes, has been used in Greece from 300 BC, where during the growing season of grains like wheat and barley, legumes are grown different times. According to El-Gobashy et al. [16], IC systems with legumes in symbiosis have the potential to boost environmental resources and crop yields by supplying nitrogen nutrients. The potential contribution of traditional mixed crops to the global food supply is between 15 and 20 percent. Intercropping with corn is quite common in Latin America. Intercropping is quite frequent in Malawai and takes up 94% of the cultivated soil, whilst in Africa 89% of cow peas and 90% of peanuts are planted in mixed stands [17]. Peksen and Gulumser [18] also reported that alternate row planting, a planting rate of 2M:1B, and simultaneous planting of component crops is advised due to its simplicity, ease of application, and suitability for use in the majority of situations encountered by common farmers.

Management is also practiced, including the application of fertilizers, both organic and artificial, to improve the yield of intercropping farming and protect soil health. Growing sweet corn can benefit from the large nutrients that organic fertilizers can provide when applied either directly or after composting or other procedures. In conventional agriculture, organic fertilizers are frequently employed as a supplement to fertilization or to enhance the soil's characteristics, and they are required in organic farming [17]. Evaluation is challenging due to intercropping systems' complexity and variety. The adoption of intercropping systems should be conceptualized focusing the potential costs and the overall advantages for both the public and commercial sectors to lessen this complexity. By improving the efficiency of how much water, nutrients, and radiation are used, intercropping can improve crop yields and revenue.

The doses and rate at which organic matter decomposes to release nutrients or create organic soil in matter ponds determines the potential utility of animal feces as fertilizer and soil enhancer. Simply increasing the diversity of the cover crop in corn production systems will have little impact on ecosystem services, but creating polycultures that promote functional diversity can result in a multifunctional agriculture environment [19]. Cow manure includes the mineral N [20]. In contrast to compost (agricultural waste), which has N, P, and K content of 0.51-0.53%, 0.21-0.23%, and 0.60-0.65%, respectively, as its mineral nutrients, chicken manure contains 6.99-7.78% N, 0.89-099% P, 4.88-5.70% K, 37.80-38.09% organic matter, 0.39-0.86% bulk density, and 31.00-60.40% total porosity [21]. Based on the report of Nguyen et al. [22], adding compost + mulch or compost alone can increase available water and air exchange tomato cultivation, whereas Abouziena and Haggag [23] reported that straw mulch was consistent in controlling weeds and had an effect on soil chemicals properties and had a low effect on apple fruit yield. In contrast, according to Hossain et al. [24], straw mulch was able to improve mung beans' growth and yield by up to 31.25%. Atakora et al.[25] reported that green manure affected plant height, number of leaves, root diameter, root length, and yield in carrot. Nitrogen is an essential element that is required both in term of affecting plant productivity and negative environmental effects. For better nitrogen management, it is important to quickly and nondestructively measure leaf nitrogen concentrations and leaf mass per area. Growing N-fixing legumes in rotation with sweet corn can be the primary supply of N in an organic system. The addition of fertilizers, specifically nitrogen, phosphorus, and potassium (NPK), has long been the means by which the cultivated area in irrigated agriculture has increased globally. Even less information is known about the impact of applying mixed manure and NPK to the soil on crop output (Ahmed et al., 2020)[26]. Widespread usage of nitrogen fertilizers has increased crop productivity, yet insufficient N input has led to low yield and food shortages. Up to 50% of the nitrogen from fertilizers applied to agricultural soil is lost to the environment in today's intensive agricultural production system [27].

MATERIALS AND METHODS

The study was a field experiment conducted in Giwangan Subdistrict, Umbulharjo, Yogyakarta. The experiment site was located at an altitude of 115 m above the sea level, with temperature range of 18 to 26^{0}C, humidity of 50-90%, 200 cc of rainfall per month, and strong light intensity. The soil type is gromusol, with pH of 5.6 to 6.6. The experiment was set up in a Randomized Complete Block Design with two factors (factorial) and three replications. The first factor was organic fertilizers source (cow manure, chicken manure, and waste compost at rates of 20 ton ha^{-1}), and the second one was the doses of NPK compound fertilizer (200, 300, and 400 kg ha^{-1}). Control treatment was also made using cow manure, urea, TSP, and KCl fertilizers.

The steps of the research consisted of making experimental plots, soil preparation, basic fertilization with the application of organic fertilizer according to the treatments, seed selection, and planting. The planting space used for sweet corn and soybean was 75 x 25 cm and 25 x 25 cm, respectively, resulting in two soybean plants planted between two rows of corn plants. Watering was done on days without rain. Plant pest was controlled manually by picking, killing and burying the pests, and weed was controlled by weeding. Plants that ere 1 (one) month old were destroyed to observe growth variables. After that, generative growth variables were observed till harvest. Observed variables for soybean and sweet corn include fresh and dry weight per plant, fresh weight of sweet corn cobs and soybean pods, chlorophyll content, vitamin C, pro-vitamin A, and sweetness level of sweet corn seeds and soybean. Efficiency land variables include the Land Equivalent Ratio (LER), Land Equivalent Coefficient (LEC), Competition Index (CI), Crop System Efficiency (CSE), System Productivity Index (SPI), Relative Yield Total (RYT), and Relative Yield Mixture (RYM). The data were analyzed using analysis of variance at a significance level of 5% and continued with Duncan's Multiple Range Test at a significance level of 5%.

RESULTS

There was no interaction effect of NPK fertilizer doses and organic fertilizer sources on the number of seed row^{-1} and cob weight ha^{-1} (Figure 1). The sources of organic fertilizer did not significantly affect the number of row cob^{-1}, but significantly affected cob weight ha^{-1}, in which chicken manure produced higher cob weight ha^{-1} than cow manure and waste compost. Similarly, NPK fertilizer doses did not significantly affect the number of row cob^{-1} but significantly affected cob weight ha^{-1}, in which 200 kg ha^{-1} of NPK fertilizer showed lower results than 300 – 400 kg ha^{-1} of NPK fertilizers.

Interaction effects of NPK fertilizer doses and organic fertilizer sources were not observed on the level of sweetness and pod weight ha^{-1} of soybean. The sources of organic fertilizer significantly affected the sweetness level, in which sweetness level of soybean treated with waste compost was lower than that treated with chicken and cow manure. Likewise, the NPK fertilizer dose did not significantly affect sweetness level of soybean, but significantly affected pod weight ha^{-1}, in which 200 kg ha^{-1} of NPK fertilizer resulted in lower pod weight ha^{-1} than 300 – 400 kg ha^{-1} NPK fertilizers (Figure 2).

There was interaction effect of NPK fertilizer doses and organic fertilizer sources on the vitamin C content, pro-vitamin A and sweetness level of sweet corn (Figure 3). The highest vitamin C content of sweet corn was produced by cow manure or waste compost combined with 400 kg ha^{-1} NPK fertilizers, while the lowest was obtained in the combination of chicken manure and 400 kg ha^{-1} NPK fertilizers. The highest pro-vitamin A was produced by chicken manure combined with 300 – 400 kg ha^{-1} NPK fertilizers. The highest sweetness level of sweet corn was in the combination of chicken manure and 200 – 400 kg ha^{-1} NPK fertilizers or in the combination of waste compost and 400 kg ha^{-1} NPK fertilizers.

There was an interaction effect of NPK fertilizer doses and organic fertilizer sources on the percentage of 2-3 seed pod^{-1}, vitamin C content and pro-vitamin A content in soybean. The highest of percentage of 2-3 seed pod^{-1} was produced by chicken manure combined with 400 kg ha^{-1} NPK fertilizers, while the lowest was in the combination of chicken manure and 100 kg ha^{-1} NPK fertilizer. The highest vitamin C content was produced by chicken manure combined with 300 kg ha^{-1} NPK fertilizers, while the lowest was in the combination of waste compost and 400 kg ha^{-1} NPK fertilizers. The highest pro-vitamin A content was observed in the combination of waste compost and 400 kg ha^{-1} NPK fertilizers, while the lowest was in the combination of chicken manure and 300 kg ha^{-1} NPK fertilizers. The best values of efficiency land (LER, LEC, CI, SPI, RYM and RYT) were produced by chicken manure combined with 400 kg ha^{-1} NPK fertilizer (Table 1).

DISCUSSION

There was an interaction effect of the organic fertilizer sources and the doses of NPK compound fertilizer on the number of seed rows, cob weight ha^{-1}, the sweetness level of sweet corn, and the weight of soybean pod ha^{-1} (Figure 1). The sources of organic fertilizer did no significantly affect the number of seed rows of sweet corn, nor did the doses of NPK fertilizer (200-400) kg ha^{-1}. This condition can indicate that the nutrient content in the soil is sufficient or the nutrients in the organic fertilizer and NPK fertilizer given are low so that it does not affect the number of seed rows of sweet corn. This is not in accordance with the report by Paikra et al. [28], mentioning that the combination of manure with recommended NPK fertilizer (120: 60: 40) increased seed rows cob^{-1} of sweet corn.

The sources of organic fertilizer significantly affected the weight of cob ha^{-1} of sweet corn, so did the doses of NPK (200-400) kg ha^{-1}. The sources of chicken organic fertilizer showed significantly higher weight of cob ha^{-1} than organic cow manure and waste compost, while cow manure organic fertilizer and waste compost gave no different results. This is not in accordance with the opinion of Murmu et al. [29], stating that the application of organic vermicompost with mineral fertilizer increased the productivity of tomato and sweet corn plants in an intercropping system. Likewise, Paikra et al. [28] reported that the combination of manure with NPK fertilizer recommendations (120:60:40) increased the weight of cob ha^{-1} of sweet corn.

The sources of organic fertilizer significantly affected the sweetness level of corn and soybean, while the doses of NPK fertilizer (200-400) kg ha^{-1} had no effect (Figure 2). The sweetness level of soybean was significantly higher when given organic chicken and cow fertilizers. Wailare [5] reported that giving a combination of organic vermicompost fertilizer with recommended NPK fertilizer increased the sweetness level of baby corn seeds.

The sources of organic fertilizer significantly affected the weight of pod ha^{-1} of soybean, so did the doses of NPK fertilizer (200-400) kg ha^{-1}. The source of chicken manure showed that the weight of pod ha^{-1} was significantly higher but not significantly different from cow manure, while waste compost was significantly different. This is not accordance with the opinion of Murmu et al. [29], reporting that applying organic vermicompost with mineral fertilizers increased the productivity of tomato and sweet corn plant in an intercropping system. Likewise, Paikra et al. [28] reported that the combination of manure with NPK fertilizer recommendations (120:60:40) increased the weight of cob ha^{-1} of sweet corn.

An interaction effect was observed between organic fertilizer sources and the doses of NPK compound fertilizer on the content of vitamin C, pro-vitamin A of sweet corn and soybean, and land efficiency including LER, LEC, CI, CSE, SPI, RYT and RYM, while there was no interaction effect on the sweetness level of soybean seeds (Figures 3, 4 and Table 1). The high vitamin C content of sweet corn was produced by cow manure or waste compost combined with NPK fertilizer at a dosage 400 kg ha^{-1}. This condition shows that the nutrient content of cow manure or waste compost and NPK fertilizer at 400 kg ha^{-1} can increase the sweetness of sweet corn. This is in accordance with Pangaribuan et al. [30], stating that chicken manure combined with urea at 300 kg ha^{-1} increased the sweetness level of sweet corn. Likewise, Ahmed et al. [26] reported that increasing the dose of N fertilizer increased the ascorbic acid of Cactus Pears Fruits. Meanwhile, the application of cow manure and 100 kg ha^{1} NPK fertilizer was able to reduce sweetness level of sweet corn, which is not in accordance with Taeotankencan et al.[31], mentioning that the *Artemisea lactiflora* produced high vitamin C when treated with cow manure.

The combination of chicken manure and NPK fertilizer at doses of 300-400 kg ha^{-1} was able to increase the pro-vitamin A content of sweet corn. This shows that the nutrient content of chicken manure and 300 kg ha^{-1} of NPK fertilizer can meet the needs of sweet corn and affect the sweetness level of sweet corn. This is supported by the Wailare [5], reporting that the combination of organic vermicompost fertilizer and recommended NPK fertilizer increased the sweetness level of baby corn seeds. Meanwhile, applying 100 kg ha^{-1} cow manure and NPK fertilizer was able to reduce the pro-vitamin A content.

The high level of sweetness of sweet corn seeds was produced by cow manure or waste compost combined with 400 kg ha^{-1} NPK fertilizer. This condition shows that the nutrient content of cow manure or waste compost and NPK fertilizer at a dose of 400 kg ha^{-1} can increase the sweetness level of sweet corn. Wailare [5] reported that application of the combination of organic vermicompost fertilizer and recommended NPK fertilizer increase the sweetness level of baby corn seeds. This is in accordance with Pangaribuan et al.[30], mentioning that the combination of chicken manure with urea at 300 kg ha^{-1} increased the sweetness level of sweet corn. Meanwhile, the application of cow manure and 100 kg ha^{-1} NPK fertilizer was able to reduce sweetness level of sweet corn,

The percentage of 2-3 seed pod^{-1} of vegetable soybean was influenced by the combination of chicken manure and 400 kg ha^{-1} NPK. Paikra et al.[28] reported that a combination of chicken manure with nitrogen fertilizer recommendations (120: 60: 40) increased the pod weight of soybean.

The highest vitamin C content of soybeans was produced by chicken manure combined with 300 kg ha^{-1} NPK fertilizer. This condition indicates that the nutrient content of cow manure or waste compost and NPK fertilizer at 300 kg ha^{-1} can increase the vitamin C content of soybean seeds. Meanwhile, the application of cow manure and 100 kg ha^{-1} NPK fertilizer can reduce the vitamin C content of soybean seeds. This is not in accordance with the report of Taeotankencan et al.[31], mentioning that in *Artemisea lactiflora* produced high vitamin C when treated with cow manure.

The combination of chicken manure and NPK fertilizer (300-400) kg ha^{-1} was able to increase pro-vitamin A content of soybean. This is supported by Sardar et al. [32], reporting that the combination of liquid organic fertilizer with the micromineral Zn, B could increase the carotenoid (pro-vitamin A) content of broccoli (*Brassica oleracea*). Meanwhile, applying cow manure and 100 kg ha^{-1} NPK fertilizer could reduce the pro-vitamin A content.

Intercropping of sweet corn and soybean has a very high land efficiency, as shown by the Land Equivalent Ratio value of 1.54. Other efficiency metrics include Crop System Efficiency, Relative Yield Total, and Competition Index. The findings of numerous research, one of which was Bantie et al. [33], showed that intercropping lupine and barley crops increased land efficiency by increasing the Competition Index, Land Equivalent Ratio (LER), and Area Time Equivalent Ratio (ATER).

According to Dhonde et al. (2016)[34], the Land Equity Ratio increased to 1.15 in the intercropping system of corn and long beans in a 2:2 arrow ratio. A bigger yield advantage over monoculture is often indicated by the higher LER value. Aswe and Maimela (2020)[35] also reported an increase in yield, grain yield, LER, and yield when cowpea and corn were intercropped. LER, ATER, A, and CR were higher than sesame and were not affected by the cropping pattern. Additionally, compared to sesame monoculture, planting cotton alongside sesame provides better financial advantages [36]. The method that produced the maximum seed yield was intercropping two rows of cowpea plants between rows of corn. According to Nawar et al.[37], the land equivalent ratio is higher for each intercropping. By applying 30 kg ha^{-1} of P fertilizer and raising the land equivalent ratio, the yield of long beans and corn in the intercropping system can be increased [38].

According to Mekuanint [39], the competition index value of 0.92 indicates that corn is more dominant than members of the legume family. In this intercropping, the Land Equivalent Ratio (LER) value is 1.26, the Land Equivalent Coefficient (LEC) value is 0.3, and the System Productivity Index (SPI) value is 1.94. This is based on the report of Abdel-Wahab [39], which states that the intercropping of giza 22 soybean increases the density of sweet corn plant from 33% to 67%.

CONCLUSION

Based on the statistical analysis and discussion, there was no interaction between organic fertilizer sources and NPK fertilizer doses on the number of seed rows per cob, weight of cob, sweetness level of soybean and weight of pod ha^{-1}. The highest values of content of vitamin C, pro-vitamin A, number of seed rows, number 2-3 seed pod^{-1} and sweetness level of soybean and sweet corn, land equivalent ratio, land equivalent coefficient, competition index, system productivity index and relative yield mixture were produced by chicken manure combined with NPK fertilizer at doses of 300 -400 kg ha^{-1} fertilizer.

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Figures

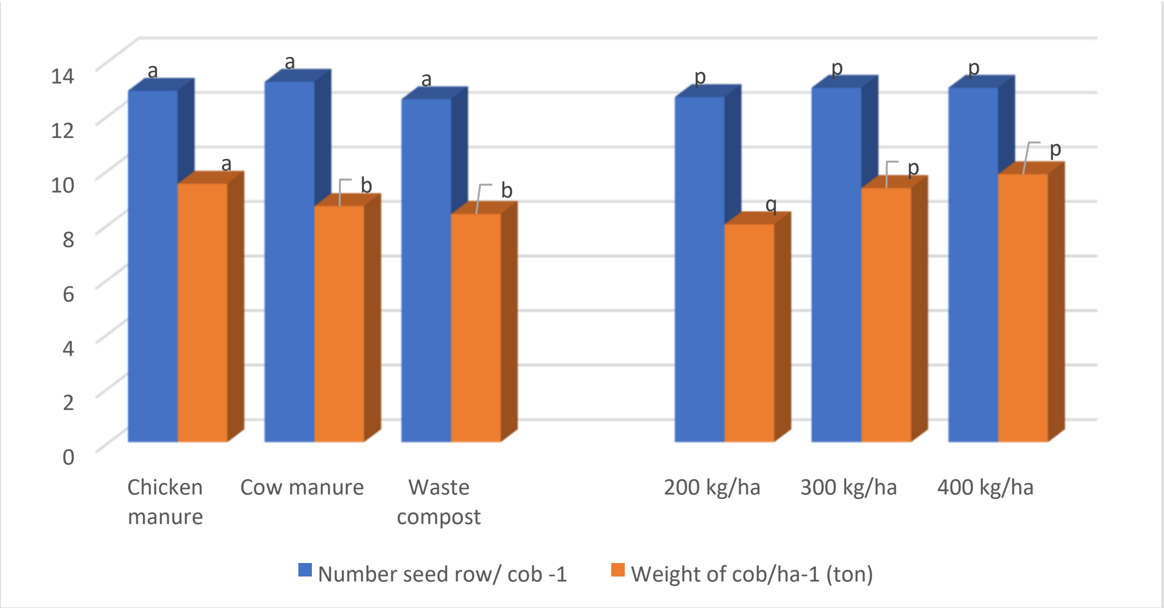

Figure 1. Number seed row and weight of cob of sweet corn

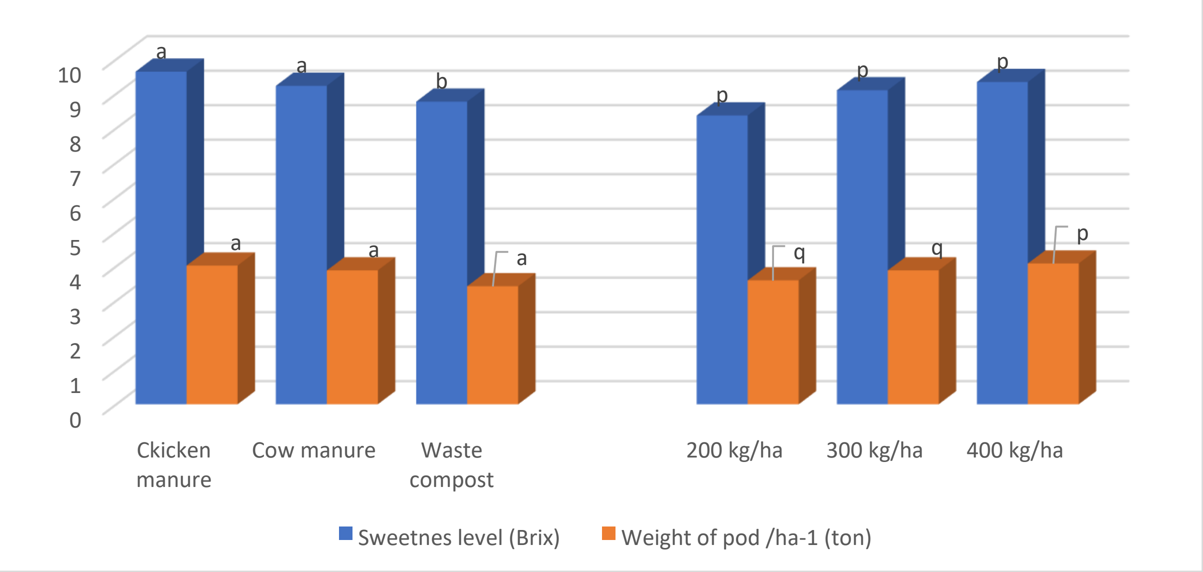

Figure 2. Sweetness level and weight of pod of vegetable soybean

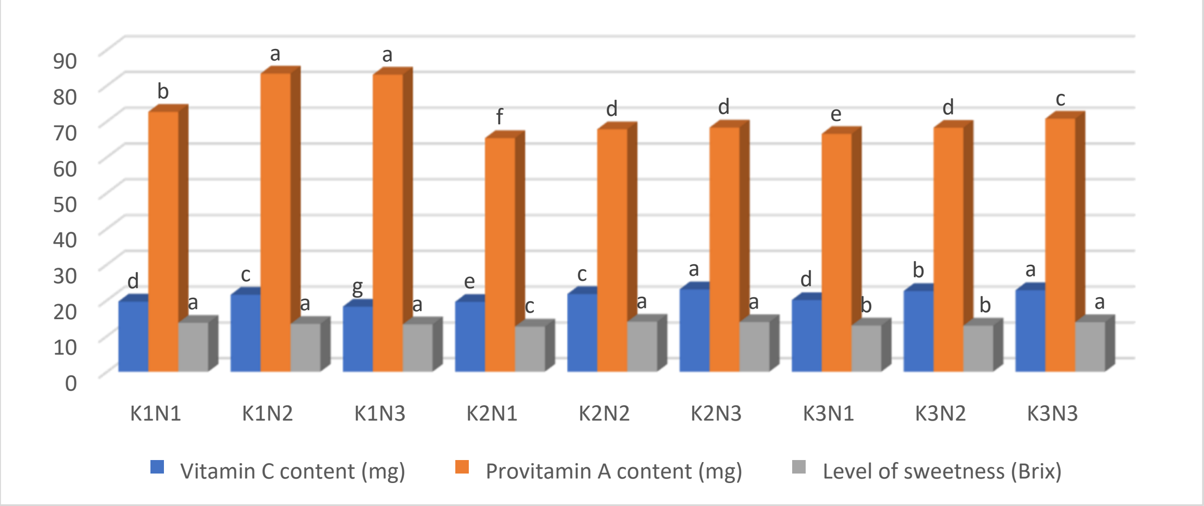

Figure 3. Vitamin C content, Pro- vitamin A content and Level of Sweetness of Sweetcorn

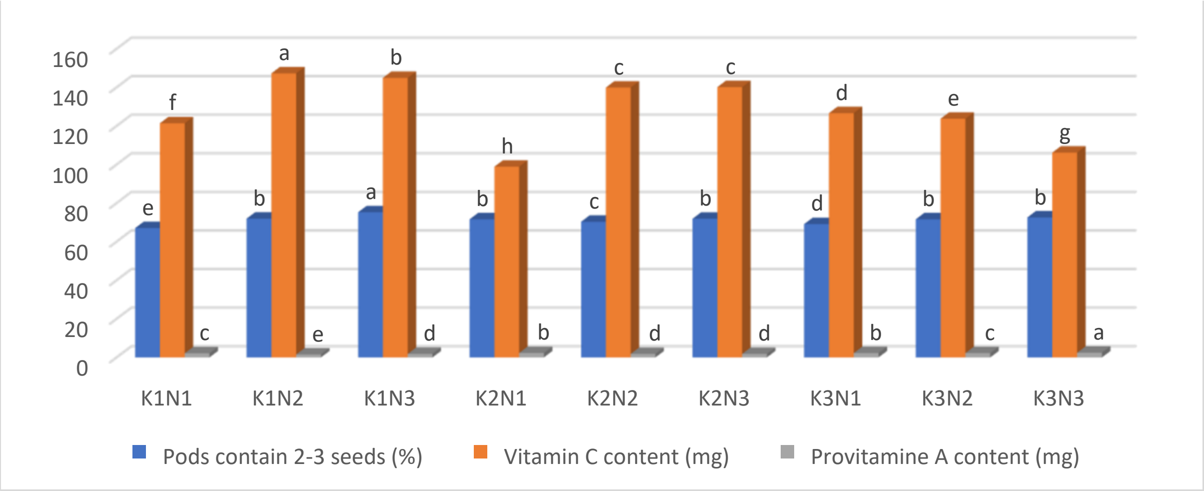

Figure 4. Pod contain 2-3 seeds, Vitamin C content and Pro-vitamin A content of Vegetable Soybean

TABLE

Table 1. Assessment of intercrop productivity LER, LEC, CI, SPI, RYM and RYT

Treatment	**Variable of Land Efficiency**					
	LER	LEC	C I	SPI	RYM	RYT
K1N1	1.42	0.50	0.85	7.77	2.26	0.92
K1N2	1.45	0.52	0.92	7.99	2.46	0.97
K1N3	1.54	0.59	0.90	8.28	2.48	0.99
K2N1	1.22	0.37	0.79	6.34	1.24	0.93
K2N2	1.31	0.42	0.81	6.63	1.36	0.97
K2N3	1.35	0.44	0.85	7.99	1.48	0.99
K3N1	1.28	0.40	0.71	6.30	1.34	0.85
K3N2	1.31	0.42	0.79	6.64	1.38	0.90
K3N3	1.33	0.44	0.82	7.08	1.48	0.99

Note. Sources organic fertilizers: chicken (P_1), cow (P_2), waste compost (P_3); dosages of NPK fertilizers 200 (N_1), 300 (N_2), 400 (N_3) kg ha^{-1}

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